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PUMPING GROUND WATER FOR IRRIGATION AND DRAINAGE

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INTRODUCTION

Pumping ground water is a means of accomplishing both irrigation and drainage. This fact is amply demonstrated in California, Arizona, Colorado, New Mexico, Utah and other parts of the Western United States. Yet plans for basin-wide development of T.V.A., the Missouri Valley, the Columbia Basin, and other basins hardly mention ground water. Perhaps inclusion of both surface water and ground water as an integrated part of the plans would unduly delay development. Data needed in planning for ground water utilization are woefully meager, and many legal and administrative problems are involved. These have been factors which have delayed utilization. On the other hand, any development of ground waters in these basins in the future must come as an afterthought or as a result of haphazard effort by individuals which has characterized many underground water developments of the past.

The costs of irrigation projects of the future stagger the imagination. Before these immense sums are expended, consideration should be given to utilization of ground water and ground water storage reservoirs, along with surface water development, as an integral part of the development of the water economy of the basin. Ground water reservoirs may have advantages over surface reservoirs. They may provide economical hold-over storage for many years with minimum evaporation losses. Also, utilization of ground water produces twin benefits—additional water is provided and drainage is accomplished.

In the past 50 years the population of the United States has doubled and both agriculture and industry have expanded at tremendous rates. Future demands will increase. To meet these demands, many states are seeking to develop their "last water holes".

The National Security Resources Board estimates that use of water will double in the near future. This increased use will result from such developments as nuclear fission, hydrogenation of coal and oil shales, supplemental irrigation in the Eastern United States, air conditioning, waste disposal, new irrigation projects in the West, expansion of industry, increase of population, and many other developments. To meet these needs, the utilization of ground water should not be overlooked. Ground water reservoirs often have tremendous "hold-over" capacities and other advantages not possessed by surface reservoirs. Moreover, pumping from underground reservoirs may relieve or alleviate drainage problems which to some degree always accompany irrigation. The Soil Conservation Service estimates that 8,000,000 acres of land in 17 Western States need improved drainage.

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Unrestricted, or unplanned, pumping has created problems in some areas. These problems include excessive land settlement, salt intrusion, and high pumping costs. But probably not over 5 percent of our ground water resources, as a whole, have been over developed. There are more than 100 ground water basins in the Great Basin. Only 3 of these basins may be classified as over developed. Additional means of recharging the underground reservoirs may solve the problems created by excessive pumping rates, in those areas where pumpage is excessive, if the annual recharge can be made to equal the annual draft.

Some authorities claim that ground water is our most neglected national resource. Statistics are too meager to permit accurate appraisal of such a claim. However, there is some justification for such claims. Water loving plants in the wet areas of the Western United States probably transpire on the order of 25,000,000 acre feet of water per year. This is roughly two times the annual flow into Lake Mead. This does not include evaporation from natural evaporation pans, such as Great Salt Lake, which receive part of their supply from underground sources. This great waste may suggest that our "last water holes" are in the underground reservoirs.

Ground Water Utilization in Historic Times

Primitive man in arid climates dug for water. Some suggest that he learned this from the wolf and the wild horse. Ewbanks states that "Man's ingenuity was, perhaps, first exercised in procuring water, and it is not improbable that the art of constructing wells was more rapidly carried to perfection than any other." The Bible is replete with references to wells. Meinzer states that Genesis 26 reads like a water supply paper. The earliest romances mentioned in the Bible were enacted at wells. Joseph's well in Cairo, Egypt is still in operation.

The well was, and in many countries still is, the center of religious and social activity. These countries include Southern Europe, the Middle and Far East, Latin America, and many islands of the sea. The pagans worshipped their wells, the Greeks consecrated them to their gods, the Moslems constructed mosques over them, and the Hindoos constructed their temples near important wells.

In many countries, the development of ground waters far surpassed the development of surface waters. The ghanats of Persia are one of the most extraordinary works of man. These ghanats serve not only as a source of water for municipal and agricultural purposes, but also serve as deep drains which have prevented waterlogging and alkalinity for centuries. The ancient Chinese drilled wells as deep as 3,600 ft. with primitive churn drill methods. Some of these wells were cased with bamboo.

The French developed modern drilling methods which were introduced into the United States in 1850. The first wells for culinary purposes were drilled in Charleston, South Carolina, Louisville, Kentucky, and St. Louis, Missouri. The oil drilling industry gave well drilling its greatest impetus.

Historical ground water developments illustrate the importance of ground water in the development of civilizations. The ground water development projects have usually survived the ravages of time and many are still in use, whereas many of the great historic projects to conserve surface waters are no longer in use.

Present Utilization

In the United States approximately 20 percent of the water utilized for industrial, municipal, and agricultural purposes comes from ground water sources. This ground water use is approximately 30,000,000,000 gallons per day, equivalent to a continuous flow of 46,500 cubic feet per second. This stream would produce 33,500,000 acre-feet per year or more than enough to fill Lake Mead in one year.

Approximately 14,000,000 acre-feet of ground water was utilized in 17 Western States in 1945; of this volume 11,000,000 acre-feet was used for irrigation. In 1950 California pumped about 10,000,000 acre-feet from underground sources. There are more than 54,000 wells in Arizona, California, Colorado, Idaho and Utah. If these wells were all pumped simultaneously into a common stream, the resulting flow rate would be approximately 75,000 cubic feet per second, which would fill Lake Mead in a little more than one-half year. Pumping from ground water reservoirs has become big business with a considerable investment in well-drilling machinery, wells, pumps, and water distribution facilities.

Some of the development to date has been haphazard and not according to a systematic plan based on good physical and hydrologic data. This has resulted in annual pumpage in excess of annual recharge, salt water intrusion, and growing pumping costs in a few areas.

However, the problems which have resulted from haphazard development merely emphasize the need for planned utilization and should not deter the maximum safe development of our ground water resources.

Present utilization of ground water has demonstrated the feasibility of pumping for both irrigation and drainage and has illustrated the problems which must be considered in the planned utilization of ground water in the future.

Examples of Ground Water Utilization

(1) Texas: The daily use of ground water for industry, agriculture, and municipalities is considerably more than 5,000 acre-feet. Nearly 75 percent of the urban water supply in Texas comes from underground sources. Use of ground water doubled in 9 years. In the same time, use for irrigation multiplied four times. The rate of ground water utilization in many parts of Texas far exceeds the rate of replenishment of the ground water reservoirs. This is particularly true in the high plains of Texas where the annual pumpage is estimated to be 20 times the annual recharge. In the high plains area, in 1934, there were 300 pumped wells which irrigated 16,000 acres. In 1948 there were 10,000 wells irrigating one million acres. At the present time, pumped wells irrigate approximately $2\frac{1}{2}$ million acres in the high plains region. Developments in this region illustrate the need for planned utilization of ground water so that the average annual draft can be more nearly equal to the average annual replenishment.

(2) California, Modesto Irrigation District: From 1907 to 1922 the Modesto Irrigation District spent $356,000 for construction and maintenance of regular gravity drains for 45,000 acres. In 1922 the district drilled its first drainage well. By 1939 there were 77 pumped wells which pumped 207 c.f.s. The total construction costs of the wells, pumps, and pipe lines was $159,000. The comparable cost for gravity drains and facilities was $308,000. The operation and maintenance costs for the pump system was $60,050 as compared to

$148,700 for the gravity drains. Power costs for pumps was $393,100. But the value of the pumped water utilized for irrigation at $1.36 per acre foot was $612,050. The cost of drainage with the open drains was prohibitive. Thus, pumping from ground water sources produced both irrigation and drainage benefits at a considerable financial advantage to the Modesto District.

(3) California, Central Valley: Ground water development has been rapid since 1910. By 1919 the total capacity of wells in the San Joaquin Valley was 7300, and by 1929, 20,600 cubic feet per second. The usable underground reservoir capacity is about 20,000,000 acre feet. In 1948 there were approximately 35,000 pumped wells in the San Joaquin Valley, with a gross pumpage of 7,000,000 acre feet. The annual recharge is approximately 2,000,000 acre feet. Plans are underway to increase the recharge. Pumping ground water in the Central Valley has practically eliminated drainage problems. Utilization of underground storage reservoirs makes deep percolation and seepage from canals and ditches relatively unimportant so far as utilization of water in the basin as a whole is concerned.

Utilization of ground water, and of the reservoirs which store it, is of tremendous economic importance in the Central Valley of California. Surface storage reservoirs cannot compete with the great underground reservoirs. Although the annual use from the reservoir exceeds the annual recharge rate, it is premature to say that development has been excessive until all possibilities for increasing the annual recharge have been fully developed. When a surface reservoir fails to fill, we explore means of getting additional water into the basin. Why not refill our ground water reservoirs in the same manner?

(4) Arizona, Salt River Valley: Irrigation was greatly expanded in the Salt River Valley by completion of the Roosevelt dam. Drainage became a problem in 1918. Drainage problems usually follow on the wake of irrigation developments. The Salt River Valley Water Users Association pumped 50,000 acre-feet of ground water in 1920 and 1921 as a means of alleviating the drainage problem and at the same time providing additional irrigation water. The volume of pumped water was increased to 100,000 acre-feet in 1922, and in 1948 the total was 400,000 acre-feet, one-third of the irrigation water supply. The water table is now at an average depth of about 50 feet. Pumping ground water has solved the drainage problem.

This is a good example of the twin benefits produced by utilization of ground water.

(5) A Private Ranch in Idaho: The benefits of pumping ground water for both irrigation and drainage are illustrated by development on a ranch in Idaho. This example is cited because of its simplicity and because the developments were within the economic reach of an individual farmer, and his enterprising sons. But this simple example illustrates on a small scale some of the possibilities for development on a much larger scale of many ground water reservoirs of the West. Twenty years ago this ranch was a marginal enterprise largely because of an inadequate supply of late season water for the higher lands and because of waterlogging of lower lands. This same paradox exists in many areas of the West—low productivity of higher land because of an inadequate water supply and reduced productivity on lower lands because of too much water.

Part of this ranch was on a bench with shallow, highly permeable soils which could not be irrigated without excessive seepage from irrigation ditches and deep percolation losses from the irrigated soils. Also, the land was steep so that excessive surface run-off accompanied irrigation. Part of the ranch

was low-lying river bottom land which produced poor pasture grasses and other water-loving plants, with high consumptive use rates. The water losses from the higher lands produced waterlogging of the lower lands.

A ravine extended through the ranch. The ravine was rather deep through the upper lands and shallow through the lower lands. It served as a natural drainage-way for irrigation waste water from upper lands and also for flood waters from precipitation and snow-melt. Flow in the ravine was erratic, but it contributed to the drainage problem on the lower lands. The rancher's best water right from the point of view of volume of water, priority, and seasonal distribution was on the ditch which served the lower lands. He never failed to use his water on these lower lands, even though the soil was already filled with water because he feared that he might lose his right through disuse. Thus, he further contributed to the drainage problem.

The rancher and some of his neighbors had high hopes that the dam on the river, from which they received their water, would be raised so that additional late-season water could be provided for the high bench lands. But this proved uneconomical. He began to think about his problem and with a little technical assistance solved it himself.

Here is the solution which he and his sons produced. The water in the lower canal was transferred to the higher land. This provided adequate water for the higher land. Two pumped wells were installed on the low-lying land. The rancher's sons purchased an old well-drilling rig, repaired it, and drilled their own wells. A small dam was built across the ravine with the rancher's own equipment during the slack season on the ranch. This provided a small reservoir of about 50 acre-feet storage capacity. The reservoir fills 2 or 3 times during a season from waste water from the higher lands and from flood waters. Water from the surface reservoir and from the two pumped wells provides an ample water supply for the lower lands. The rancher does not worry too much about excessive seepage from his ditches and reservoir, for these waters are nearly all reclaimed by the two pumped wells. In addition, the water table on the low lands has been lowered sufficiently to make his pastures highly productive. The difference in consumptive use between the water-loving plants and high-grade pastures has resulted in a net savings in water. Even though the consumptive use had been the same, the exchange of a poor pasture for a good one was good business for the rancher. His ranch has been transformed from a marginal operation to a profitable enterprise.

This example could be followed with profit by many individual farmers. The principles illustrated in it should be considered in the planned utilization of our water resources on a basin-wide scale.

Problems of Development

Adequate consideration of ground water in the planning of water development projects of the future is urgently needed, but the problems in ground water development are many and varied. Most of these problems can be classified as physical, legal, and administrative.

Physical Problems: The physical problems arise from our lack of basic hydrologic and geologic data. If our water resources are to be fully and efficiently utilized, we must inventory nearly every aspect of the hydrologic cycle. We have done a fair job in the measurement of precipitation and surface runoff, but no phase of the hydrologic cycle has been completely inventoried. Data on the ground water aspects of the hydrologic cycle are particularly meager. Good basic data are indispensable to planned utilization. The

lack of these data has been a contributing factor in the inadequate consideration given to ground water in water development projects. The recommendations of the Hydrologic Subcommittee on basic data needs are inadequate regarding the ground water phases of their report. This illustrates one of the difficult problems which must be solved if ground water is to receive ample consideration in water plans of the future.

Geologic data on the size, configuration, and water yielding capacities of underground water reservoirs are also meager. The costs of obtaining good data are high, but if we can afford the millions of dollars, and sometimes billions, needed for the construction of some of the projects proposed for the future, we can afford the costs of obtaining good basic data upon which to base such tremendous expenditures. This will insure sound development for the future.

Legal Problems: Legal definitions, classifications, and concepts have tended to limit development and full utilization of ground waters in some areas. The mere fact that we have classified and separated surface water from ground water, and in many instances applied different rules to them, has limited the development of ground water. We need uniform policies and rules in the administration of all waters, whether they be above or below the ground. Actually, underground and surface waters are so closely related in the hydrology of a basin that it is "academic" and impractical to try and separate them.

Some court decisions have tended to limit future development of ground waters. Part of this difficulty stems back to the lack of basic data, and partly to the failure of the courts to make due allowances for changing conditions and demands. In Utah, for example, persons have been restrained from pumping ground water because such pumping lowered artesian pressures sufficiently to prevent prior artesian wells from flowing. This is similar to guarantee of the means of diversion on surface streams, a practice not followed by Utah in dealing with surface water. In some states there is no legislative or constitutional control of ground water development. Control is based largely on court decisions. But often court decisions are delayed until irreparable damage has occurred.

These legal difficulties must be resolved. They will be difficult to resolve, but probably not more difficult than the consummation of a river compact or of the working out of the large number of water right exchanges that will be required in many of the water development projects proposed for the future.

Administrative Problems: The coordinated development and utilization of ground waters and surface waters on a basin-wide, and frequently an interbasin, basis will require the solution of many administrative problems. There shall need to be closer coordination of the efforts of separate agencies which deal with surface and underground waters. Perhaps these separate agencies should be merged into one overall agency which can plan, develop, and administer all waters in an integrated fashion. Another problem will be that of making appropriate water transfers so that surface waters may be utilized on higher lands and pumped water on lower lands. Lowering of the water table on low lands to reduce consumptive waste and to improve drainage will alter the regimen of streamflow on the lower sectors of streams. These are some of the important administrative problems for which equitable solutions must be obtained.

CONCLUSIONS

Ground water is a neglected natural resource. Basin-wide plans for development of many of our great river systems hardly mention the utilization of ground water. Existing developments demonstrate the economic importance of ground water and the need for planned utilization. They also demonstrate the fact that utilization of ground water produces twin benefits—drainage and additional irrigation water. Physical data, legal concepts, and administrative principles and practices must be improved and developed to stimulate sound development of this important resource.

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c. Discussion of several papers, grouped by Divisions.
d. Presented at the Atlanta (Ga.) Convention of the Society in February, 1954.
e. Presented at the Atlantic City (N.J.) Convention in June, 1954.

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